NAVAL HEALTH RESEARCH CENTER

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EXECUTIVE SUMMARY

Problem

The 6-on/12-off schedule aboard submarines closely approximates laboratory protocols designed to cause human circadian rhythms to free run at the unique cycle length of each individual's circadian clock (generally longer than 24 hr). Therefore, circadian rhythms among submarine personnel working on this schedule may free-run, which could have ramifications for performance and sleep.

Objective

The objective of this study was to determine whether submariners do show free-running circadian rhythms and to provide associated sleep and performance measures.

Approach

Submariners working the 6-on/12-off and other schedules were monitored. Measures included a physiological circadian rhythm (salivary melatonin), the sleep-wake pattern (actigraphs and sleep logs), and cognitive performance (performance assessment battery [PAB] testing on hand-held computers at the end of duty periods). This report provides a preliminary discussion of the sleep-log, actigraph, and PAB data.

Results

Actigraph and sleep-log data demonstrate that in 6-on/12-off personnel, sleep periods moved through the 24-hr day, consistent with the 18-hr day. However, there continued to be a greater proportion of sleep during the nighttime hours than the daytime, particularly during the first part of the voyage. Subjects averaged a little less than 7 hr of sleep per 24 hr, with individual sleep episodes averaging 5.5 hr in duration. Accuracy and speed on one of the PAB tasks were very consistent across the three segments of the voyage, suggesting no accumulating negative effects from the work schedule. Mood and alertness also remained relatively even.

Conclusion

Preliminary analyses suggest that submarine personnel are able to obtain adequate sleep and maintain adequate performance while working the 6-on/12-off schedule. The lack of commutes to and from work and of social/family obligations undoubtedly make this schedule more workable than it would be in land-based work. Future analyses will determine whether circadian rhythms free run and will examine the relationships of performance and sleep with circadian phase.

ABSTRACT

Circadian rhythms are fluctuations in physiological and behavioral parameters, cycling at a rate of about once every 24 hr, which are controlled by a biological clock. The endogenous circadian clock has been shown to cycle at a rate (tau) unique to each individual that is generally longer than 24 hr (24.25-25 hr). The most accurate method for determining tau is a laboratory protocol called forced desynchrony. In forced desynchrony, subjects are isolated from time cues and bright light. The sleep-wake schedule is lengthened or shortened to the point that it is physiologically impossible for a person to synchronize with. Under these conditions, circadian rhythms free run at the cycle length of the endogenous clock. The submarine 6-on/12-off schedule is very similar to such protocols, requiring subjects to live by an 18-hr day under conditions of isolation from bright light. A study of personnel living on this schedule aboard a submarine was completed. Measures included the circadian rhythm of salivary melatonin, sleep logs, actigraphs, and a performance assessment battery (PAB) administered on hand-held computers. Preliminary results from the PAB, the sleep logs, and the actigraphs are presented. Subjects appear to get sufficient sleep and to maintain acceptable performance levels on this work schedule.

INTRODUCTION

This paper will discuss the interaction of endogenous human circadian rhythms with unusual work schedules, and it will present some preliminary data from a study of a submarine work schedule. Circadian rhythms are fluctuations in physiological and behavioral parameters, cycling at a rate of about once every 24 hr, which are controlled by a biological clock. Figure 1 shows the typical circadian rhythm of body temperature in an individual synchronized to local time. Body temperature is the physiological measure most frequently used as a marker of circadian rhythms. Alertness and many types of performance show rhythms generally in phase with that of body temperature. Therefore, humans have difficulty maintaining alertness during the lowest temperature part of the cycle, and if sleep occurs during the higher temperature portions of the cycle it tends to be disrupted or shortened.

[Figure 1 about here]

Being evolutionarily designed to be awake and alert during the daytime and to sleep at night conflicts with the modern requirement for 24-hr coverage in many military and civilian jobs. Even individuals who work the night shift for many years don't show complete adjustment of circadian rhythms to the transposed sleep-wake cycle (Monk, 1986; Tepas & Mahan, 1989), and night workers consistently average less sleep than day workers (Tepas & Mahan, 1989). The night shift, with its total reversal of sleep and wake, conflicts with physiological circadian rhythms. However, at least partial adaptation can occur to long term night work (Folkard, 1992; Knauth, 1993; Monk, 1986;

Wedderburn, 1992; Wilkinson, 1992). Some types of rotating shift-work schedules may allow even less adjustment. The 6-on/12-off schedule, which requires the individual to live on an 18-hr day, is a unique type of rapidly rotating schedule. This schedule is used for up to 70% of the ships' company onboard U.S. Navy submarines. While rapidly rotating shift-work schedules sometimes are advocated (eg, Knauth, 1993), this generally is premised on maximizing the individual's opportunity to live (and sleep) by a diurnal pattern. The 6-on/12-off schedule does not do that. It is somewhat analogous to 6 hr of eastward-travel jet lag each day, requiring a totally non-24-hr sleep-wake schedule.

The 6-on/12-off schedule is operationally valuable because it allows 24-hr coverage with only three watches. This is required by the space limitations onboard submarines. The schedule also limits the duration of each watch to 6 hr. The shorter watches are considered necessary to assure maintenance of alertness during sometimes monotonous work performed at all hours of the day. Crew members do not actually have 12 hr of free time out of every 18 hr. Supplementary duties such as maintenance, training, and drills can take many hours in addition to the official watch period. Most personnel are preparing for examinations to advance in rank, to earn college credits, or to become submarine qualified. Submarine qualification is a mandatory process for new submariners, requiring an in-depth knowledge of all ship's systems and operating procedures. Thus, many personnel spend a great deal of time studying. Intermittently, drills occur that require all hands to be up and working during the day, even those who were on watch the preceding night.

The submarine environment could have some advantages for shiftworkers. Twenty-four-hour coverage is required in many land-based situations, but all of them share characteristics that prevent full adaptation to a nondiurnal work-rest schedule. The obstructing aspects are sunlight and weekends or days off. Sunlight, or other very bright light, is the strongest entrainment signal for the biological clock (Czeisler et al., 1989; Rusak, 1979) . Sunlight exposure during the day interferes with a nocturnal orientation of the clock. On days off, social factors also tend to push individuals toward a diurnal phase position. On a submarine, personnel do not have to contend with either of these factors. They are never exposed to light other than fairly low level artificial light (Hunt & Kelly, 1995), and they do not have days off when they can sleep whenever they choose.

Theoretically, it should be quite possible to synchronize submarine personnel to be maximally alert during any part of the 24-hr cycle, as long as the work period remained consistent from day to day. However, changing the watch schedule would have many ramifications, requiring many other changes. Past experience has shown us that "armchair" theoreticians can devise schedules that look great on paper, but they fail to allow for real-world aspects that only those individuals actually living the schedule understand (Fletcher, Colquhoun, Knauth, DeVol, & Plett, 1988).

The 18-hr day schedule aboard submarines is remarkably similar to the forced-desynchrony schedules (Czeisler, Allan, & Kronauer, 1990) used in the laboratory to unmask the endogenous circadian cycle length, referred to as "tau." In forced

desynchrony, subjects are isolated from time cues and bright light. The sleep-wake schedule is lengthened or shortened to the point that it is physiologically impossible for a person to acheive synchronization with. Under these conditions subjects show free-running circadian rhythms (ie, their rhythms cycle at the rate of the endogenous clock rather than by the 24-hr day).

Curiously, humans do not show a tau of exactly 24 hr, nor do they show the normal distribution around 24 hr that might have been expected. Instead, tau is almost always longer than 24 hr. Based on isolation studies in which subjects are kept in a laboratory or a cave, isolated from time cues and bright light but allowed to control their sleep-wake and light-dark cycles, the endogenous cycle length has long been thought to be around 24.5 to 25 hr (Weitzman, Czeisler, & Moore-Ede, 1981). Using forced desynchrony, estimates closer to 24.25 hr have been obtained (Emens, Brotman, & Czeisler, 1994). It has been theorized that in isolation studies, the self-selected timing of dim-light exposure is sufficient to cause recurrent phase delays. These delays artifactually lengthen the apparent endogenous cycle length. In any case, whatever the exact range of tau, it is accepted that human clocks run slow and only with daily resetting do we remain synchronized with the 24-hr day.

The submarine 18-hr day differs from forced-desynchrony protocols in that some time cues, such as clock time, times of meals, and certain other ship activities, remain cued to the 24-hr day. However, the light-dark cycle is by far the most important time cue. Without this, some blind individuals, exposed to all other normal time cues, still

cued to the 24-hr day. However, the light-dark cycle is by far the most important time cue. Without this, some blind individuals, exposed to all other normal time cues, still show free-running circadian rhythms, with periodic difficulty sleeping at night and remaining awake during the day (Folkard, Arendt, Aldous, & Kennett, 1990; Klein, Martens, Dijk, Kronauer, Seely, & Czeisler, 1993; Sack, Lewy, Blood, Stevenson, & Keith, 1991). On the submarine, the 24-hour light-dark cycle is absent, and the sleep-wake schedule is disconnected from the 24-hour day. Therefore, we expect personnel to free run.

Previous studies have shown some preliminary data suggesting submarine personnel actually do free run (Naitoh, Beare, Biersner, & Englund, 1981), but this has never been documented using a circadian marker not masked by the rest-activity cycle. If we can document the free running, the submarine environment could allow measurement of tau in an unprecedented number of people. Forced desynchrony is an extraordinarily difficult and expensive laboratory procedure, so very few subjects ever will be studied using that technique.

Free-running circadian rhythms among submarine personnel might have negative effects. It seems possible that desynchronization from all the social time cues in the environment would add to the difficulties experienced living by the 6-on/12-off schedule. Also, assigning critical duties during daytime hours, a commander may presume his crew to be maximally alert. However, if personnel free run, a daytime assignment actually may be performed at the low point of the circadian rhythm of alertness. If subjects do free

run, it should be possible to prevent this with appropriately timed bright light. Synchronizing subjects to the 24-hr day might improve quality of life. Times of lowest alertness and performance would be known and could be taken into consideration.

The purpose of the present study was to increase our understanding of the effects of the 6-on/12-off submarine schedule, to assist people in working better under such conditions. It was hypothesized that personnel would show free-running circadian rhythms of salivary melatonin and that performance, alertness, and sleep characteristics would be related to the circadian phase at which they occurred.

METHODS

This study was conducted aboard a Fleet Ballistic Missile submarine during the first 6 weeks of a routine patrol. The majority of the crew switched from their shore schedule based on the 24-hr day to a 6-on/12-off schedule involving an 18-hr sleep/wake cycle. Official ship's functions and operations, however, were based on a 24-hr day. These functions included drills, meetings, and other "all hands" events, most of which were mandatory regardless of when they fell in an individual's sleep/wake cycle. Meals were served every 6 hr, around the clock, and most ship's spaces, with the exception of individual berthing spaces, were lit with standard fluorescent lighting at all times. There was no exposure to sunlight throughout the 6 weeks.

Subjects: Twenty-nine volunteers participated in this study. Twenty subjects answered a sleep questionnaire, filled out daily sleep logs, and supplied saliva samples for melatonin analysis. Ten of these subjects also wore actigraphs and completed

computer performance testing at the end of each duty period.[a] An additional nine subjects provided only the sleep-questionnaire and sleep-log data. All but two subjects were enlisted personnel.[b] Nineteen of the subjects were on the 6-on/12-off schedule throughout the voyage, five subjects worked all days, one worked all nights, and four had variable schedules.

Sleep Questionnaire: A sleep questionnaire that has been used for many years in Naval Health Research Center (NHRC) sleep studies was augmented with questions about previous deployment and work schedule experience and with questions evaluating the subject's morningness-eveningness characteristics (Smith, Reilly, & Midkiff, 1989; Appendix A).

Sleep Logs: Each sleep log covered a one-week period, one line per day (Appendix B). Subjects specified the hours they worked and slept to the nearest half hour. The subjects also marked a visual analog scale (VAS) to rate their alertness level during each duty period. The accuracy of these data was compromised by several factors. Some subjects only recorded their scheduled watchstanding as work while others labeled watches, drills, maintenance periods, and the like as work periods. Likewise, some subjects noted only major sleep periods, while others recorded small naps and noted brief interruptions in sleep. Attempts were made to collect the sleep logs the morning after the

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[a]Because of the limited number of actigraphs and hand-held computers, we tried to assign these to subjects on the 6-on/12-off schedule. However, 1 of the 10 actually worked a variable schedule.

[b]Two junior officers, who worked a predominantly daytime schedule, provided only questionnaire and sleep-log data.

last day recorded on the sleep log each week. However, many sleep logs were turned in much later, often weeks later. Some subjects admitted sometimes filling out sleep logs from memory every few days or even at the end of the week. Additionally, several sleep logs were lost and subjects did not seek replacement until the next week. Therefore, several subjects had incomplete records.

Saliva Samples: Saliva samples were collected for melatonin analyses during the first 5 days of the patrol, for 2 days in the middle of the patrol (after 3 weeks), and 7 days near the end of the patrol (after 6 weeks). Melatonin was selected to be studied because it has a strong circadian rhythm, which does not appear to be significantly masked by activity patterns (Lewy & Sack, 1989). Saliva sampling was used because it is noninvasive and has been demonstrated to correlate with serum levels (McIntyre, Norman, Burrows, & Armstrong, 1987). Samples were collected by having the subject chew on a sterile cotton roll. The saliva-saturated cotton rolls were frozen for future analysis. Samples were collected around the clock except during subjects' sleep periods. The rotating schedule allowed collection of samples from all hours of the day over sequential days without interfering with subjects' sleep. During the first collection period, when subjects could be expected to be synchronized to the 24-hr day, samples were taken every 2 hr between the hours of 1000-2000 (the hours when melatonin levels should be very low), with hourly samples at other times. During the second and third collection periods, samples were always hourly.

Actigraph Data: Ten subjects wore Actigraph Programmable Activity Monitors (Precision Control Design, Inc., FWB, FL 32548, model AMA-32, Version 6.6) on their nondominant wrist for the duration of the study. The subjects were instructed to wear the units at all times except when showering or performing duties which involved a risk that the unit could become wet or damaged. The actigraphs were collected at the end of each week, the data downloaded to a portable computer, and each unit's battery replaced. This resulted in approximately 12 hr of lost recording time each week. Of the 10 actigraphs, one was lost, two failed to record data, and two more recorded only partial, and ultimately unusable, data.

Computer Performance Testing: The performance data were collected on Psion LZ-32 computers. These devices were small enough so that subjects could carry the devices with them, performing the testing wherever they were at the end of their duty periods. The PAB used was one specifically developed to study performance effects of different work schedules.[c] The PAB included: three VASs (alertness, cheerfulness, and calmness), a four-choice serial reaction time task, a variable difficulty Sternberg memory search task, and a spatial visualization task. The spatial visualization task required subjects to estimate whether arrows representing two aircraft will pass too closely to each other in their lines of travel. Subjects were instructed to run through the 6-min battery at

[c]The software was developed by Totterdell and Folkard (1992). It currently is not available commercially, but arrangements can be made on a study-by-study basis with the Technology Transfer Group in London to use it (Medical Research Council, 20 Park Crescent, London W1N4AL. Telephone: 01\71-636-5422. Fax: 071-323-1331).

the end of each scheduled 6-hr watch. The computers were collected at the end of each week for data downloading, occasionally causing a subject to miss a data-collection session. Subjects also failed to complete some sessions due to boredom or forgetfulness.

RESULTS

Data collection in this study was just completed. Therefore, only preliminary results from the actigraphs, the sleep logs, and the performance data are presented. The analyses of the saliva samples have not been completed.

Actigraph and Sleep Log Data: Figure 2 shows a typical actigraph record (data not from this study) from an individual living by a standard 24-hr diurnal schedule. Sleep periods are indicated by intervals of low activity. In Figure 2, sleep periods show moderate variation in timing and duration, but they all fall around the same time of day. Figure 3 shows a typical actigraph record from a subject in this study who was living by the 18-hr day. Here the sleep periods fall about 6-hr earlier in each sequential 24-hr cycle.

[Figures 2 and 3 about here]

Table 1 shows hours of sleep per 24 hr and the number of sleep episodes per week, as documented by actigraphs and sleep logs. Twenty-four subjects had usable sleep log data. The two leftmost columns show the data from the actigraphs (these data have been corrected based on the sleep-log data for periods when the actigraphs were off). The next two columns show sleep-log data for the subjects who wore the actigraphs, and the last two columns show sleep-log data for all of the subjects. Among the subjects who wore

actigraphs, the correlation coefficient (r) between times of sleep estimated by the two modalities was about .70 (time periods when the actigraphs were off were excluded from these analyses). Both the actigraphs and the sleep logs indicated that subjects averaged a little less than 7 hr of sleep out of every 24 hr, occurring during an average of 9.5 sleep periods per week. The average duration of an individual sleep episode was about 5.5 hr. Subjects averaged 65 hr on duty per week (including supplementary duties).

[Table 1 about here]

Figure 4 shows the distribution of sleep over the 24-hr day based on the combined actigraph and sleep log data from the second, fourth, and sixth weeks for subjects on the 18-hr schedule. The average sleep distribution among the subjects who worked a fixed diurnal schedule is shown for comparison.

[Figure 4 about here]

Performance Data: Preliminary results from the mood scales and the spatial visualization task, labeled "Vector," are shown in Table 2, along with the results from a the alertness scale that was filled out in the sleep logs.

[Table 2 about here]

DISCUSSION

Both the actigraphs and the sleep logs indicated subjects got a little less than 7 hr of sleep per 24 hr. Given that ideal sleep amount is generally considered to be 7 to 8 hr per day, this is not bad, at least as good as typical rotating shift workers in the civilian sector. That this is the case, despite the more difficult schedule, most likely relates to the

fact that these personnel do not have to deal with the usual commute to and from work and have little in the way of social demands on their time.

On average, sleep occurred in more than one episode per day. Ideally, the 7 to 8 hr of sleep per 24 hr should occur in a single nocturnal episode. In somebody following a totally regular 18-hr cycle, one 6-hr sleep period would occur every 18 hr, and an average of 9.1 sleep periods per week would be expected. Both the actigraphs and the sleep logs documented about 9.5 sleep periods per week, indicating that subjects sometimes slept more than once during a single 18-hr block. This may be related to work requirements preventing sleep occurring all in a block. Difficulty remaining asleep when sleeping at the wrong part of the circadian cycle also may have contributed.

The distribution of sleep data (Figure 4) shows considerably more daytime sleep among the 18-hr subjects than among the day workers. However, a predominance of nighttime sleep is present. The lower level of sleep occurring during the day versus the night probably relates to the fact that all drills and many auxiliary duties occur during the day. The drop in the proportion of nighttime sleep among the 18-hr subjects after the first part of the voyage may represent the circadian factor. That is, at the start of the voyage all subjects' physiological circadian rhythms should have made them better able to sleep at night than in the day. This physiological predisposition may have contributed to the predominance of nighttime sleep. If personnel free-ran, their circadian low point (the optimal time for sleep) would gradually have shifted out of the nighttime period. This shift could explain the decreased nocturnal predominance for sleep in the later parts of

the voyage.

Accuracy and speed on the Vector task were very consistent across the three segments of the voyage (Table 2). Certainly, these data show no detrimental effect of accumulating sleep deprivation, which was a possible concern. The vector task is difficult. The arrowheads are flashed on the screen very briefly. So, 85% seems like a reasonable level of accuracy.[d] Likewise, mood and alertness remain fairly even, by both measures. The alertness levels are comparable to values we have obtained from non sleep-deprived subjects in the laboratory using a similar instrument (unpublished data). After the circadian cycle is documented for each subject based on the melatonin data, the performance and mood data will be analyzed to determine whether a relationship with circadian phase, separate from time of day, can be documented.

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[d]Comparison data from subjects on a 24-hr diurnal schedule are being collected now.

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APPENDIX A: QUESTIONNAIRE Date ______________

Name ______________________ Rank/Rate ____________ Rating _____

Sex ___ Soc. Sec. # _____________ Date of Birth _________ Age ___

Current Duty Station ________________ Date Assigned ______________

Instructions: Please fill in the blanks or circle the answer that best applies to you. The completion of this questionaire is voluntary. This information will be used for research only and will not become part of your permanent service record. THE QUESTIONS BELOW ARE ABOUT YOUR USUAL SLEEP NOW. For questions 1 and 2, please use 24-hr clock time.

1. At what clock time do you usually go to bed?
   On workdays? ______
   On days off? ______

2. At what clock time do you usually wake up?
   On workdays? ______
   On days off? ______

3. On workdays, do you go to bed and get up at fixed, regular times?
   a. Always or almost always
   b. Often
   c. Sometimes
   d. Never or almost never

4. How long does it usually take you to fall asleep after lights out?
   ______Hours______Minutes

5. Do you ever have trouble falling asleep?
   a. Never or almost never
   b. Sometimes
   c. Often
   d. Always or almost always

6. If you do have trouble falling asleep, how often does this happen?
   a. Less than once a year
   b. Less than once a month
   c. About once a month
   d. 1 or 2 times per week
   e. 3 or 4 times per week
   f. 5 or more times per week
   g. Does not apply to me

7. If you have trouble falling asleep, what is it that keep you awake? (circle all that apply)
   a. Thoughts running through my mind
   b. Aches and pains
   c. Too much noise
   d. List any other _____
      ____
   e. Does not apply to me

8. If you have trouble falling asleep, do you (circle all that apply):
   a. Just lie in bed
   b. Turn on the light and read
   c. Get up
   d. List any other______
      ____
   e. Does not apply to me

9. Do you take anything to help you fall asleep?
   a. Never or almost never
   b. Sometimes
   c. Often
   d. Always or almost always

10. If you take something to help you fall asleep, what is it?
   a. Medicine prescribed by a doctor
   b. Nonprescribed medicine
   c. List any other_______
      ____
   c. Does not apply to me

11. How many times during your usual sleep period do you wake up by yourself and then go back to sleep?
    a. Rarely or never
    b. 1 or 2 times
    c. 3 or 4 times
    d. 5 or 6 times
    e. 7 or 8 times
    f. 9 times or more

12. On how many days per week does this happen?
    a. 1 or 2 days per week
    b. 3 or 4 days per week
    c. 5 or more days per week
    d. Does not apply to me

13. When you wake up during your usual sleep period, how long does it usually take to go back to sleep?
    a. 10 minutes or less
    b. 10 to 20 minutes
    c. 20 to 30 minutes
    d. 30 minutes to one hour
    e. Does not apply to me

14. Do you ever wake up too early and find you cannot go back to sleep?
    a. Never or almost never
    b. Sometimes
    c. Often
    d. Always or almost always

15. On how many days per week does this happen?
    a. 1 or 2 days per week
    b. 3 or 4 days per week
    c. 5 or more days per week
    d. Does not apply to me

16. How often do you take naps?
    a. Rarely or never
    b. Less than once a month
    c. About once a month
    d. 1 or 2 times per week
    e. 3 or 4 times per week
    f. 5 or more times per week
    g. More than once a day

17. How long do you usually sleep during your naps?
    a. 10 to 30 minutes
    b. 30 to 60 minutes
    c. one to two hours
    d. More than two hours
    e. Does not apply to me

18. Do you have disturbing dreams or nightmares?
    a. Never or almost never
    b. Sometimes
    c. Often
    d. Always or almost always

19. Overall, what kind of sleeper are you?
    a. Very good
    b. Good
    c. Average
    d. Poor
    e. Very poor

20. If you are a poor or a very poor sleeper, is this because you (mark single most important)
    a. Have trouble falling asleep
    b. Wake up and have trouble going back to sleep
    c. Have disturbing dreams or nightmares
    d. Awakened frequently by noise
    e. Wake up too early (early morning awakening)
    f. wake up tired
    g. Other____________________
    h. Does not apply to me

21. If you are a poor or a very poor sleeper, how long have you had a sleep problem?
    a. 1 to 6 months
    b. 6 months to a year
    c. 1 to 2 years
    d. 3 to 5 years
    f. 5 to 10 years
    g. As long as I can remember
    h. does not apply to me

22. Were (or are) any members of your family poor sleepers, that is, have sleep problems?
   a. Yes______ b. No______

23, If yes, which family member, or members if more than one? (circle all that apply)
   a. Father
   b. Mother
   c. Brother
   d. Sister
   e. Does not apply to me

24. Do you usually feel well-rested after you wake up and first get out of bed?
   a. Always or almost always
   b. Often
   c. Sometimes
   d. Never or almost never

25. Which choice below best describes how you usually feel for the first 2 or 3 hours after you wake up from your normal sleep period <u>on workdays</u>?
   a. Alert, wide awake
   b. High level, but not at peak
   c. Awake, but relaxed
   d. A little foggy, let down
   e. Slowed down, sleepy
   f. Fighting sleep
   g. Almost asleep

26. Which choice below best describes how you usually feel in the afternoon, between 3:00 PM and 5:00 PM?
   a. Alert, wide awake
   b. High level, but not at peak
   c. Awake, but relaxed
   d. A little foggy, let down
   e. Slowed down, sleepy
   f. Fighting sleep
   g. Almost asleep

27. Do you ever fall asleep even though you are trying hard to stay awake?
   a. Never or almost never
   b. Sometimes
   c. Often
   d. Always or almost always

28. Are you easily awakened by noise?
   a. Never or almost never
   b. Sometimes
   c. Often
   d. Always or almost always

29. How much do you smoke each day?
   a. None
   b. Less than 1 pack
   c. 1 pack
   d. 2 packs
   3. More than 2 packs per day

30. How much coffee, tea or caffeinated soda do you drink per day (if soda, circle soda)
   a. None
   b. 1 cup or 1 soda
   c. 2 to 3 cups or 2 to 3 sodas
   d. 3 to 5 cups or 3 to 5 sodas
   f. More than 4 cups or 5 sodas

31. Please list previous deployment history (use back of page if more lines are needed):

Approximate Dates (start - end)		Class of Ship/Submarine	Rating
____________	____________	____________________	__________
____________	____________	____________________	__________
____________	____________	____________________	__________
____________	____________	____________________	__________
____________	____________	____________________	__________

32. Please describe the types of schedules you have worked during onshore assignments.

____

____

____

____

____

____

33. Are you married? Yes_____ No_____

34. Do you have children? Yes_____ No_____ If so, how many? ______

35. Considering only your own "feeling best" rhythm, at what time would you get up if you were entirely free to plan your day?

0500-0630 ________

0630-0745 ________

0745-0945 ________

0945-1100 ________

36. Considering only your own "feeling best" rhythm, at what time would you go to bed if you were entirely free to plan your day?

2000-2100 ________

2100-2215 ________

2215-0030 ________

0030-0145 ________

0145-0300 ________

37. Assuming normal circumstances, how easy do you find getting up in the morning?

Not at all easy ________

Slightly easy ________

Fairly easy ________

Very easy ________

38. How alert do you feel during the first half hour after having awakened in the morning? (Check one.)

Not at all alert ________

Slightly alert ________

Fairly alert ________

Very alert ________

39. During the first half hour after having awakened in the morning, how tired do you feel? (Check one.)

Very tired ________

Fairly tired ________

Fairly refreshed ________

Very refreshed ________

40. You have decided to engage in some physical exercise. A friend suggests that you do this one hour twice a week and the best time for him is 0700-0800. Bearing in mind nothing else but your own "feeling best" rhythm, how do you think you would perform?

Would be in good form ________

Would be in reasonable form ________

Would find it difficult________

Would find it very difficult ________

41. At what time in the evening do you feel tired, and as a result, in need of sleep? (Check one.)

2000-2100 ________

2100-2215 ________

2215-0030 ________

0030-0145 ________

0145-0300 ________

42. You wish to be at your peak performance for a test that you know is going to be mentally exhausting and lasting for two hours. You are entirely free to plan your day, and considering only your "feeling best" rhythm, which ONE of the four testing times would you choose?

0800-1000 ________

1100-1300 ________

1500-1700 ________

1900-2100 ________

43. One hears about "morning" and "evening" types of people. Which ONE of these types do you consider yourself to be?

Definitely a morning type ________

More a morning than an evening type ________

More an evening than a morning type ________

Definitely an evening type ________

44. When would you prefer to rise (provided you have a full day of work--8 hours) if you were totally free to arrange your time?

Before 0630 ________

0630-0730 ________

0730-0830 ________

0830 or later ________

45. If you always had to rise at 0600, what do you think it would be like?

Very difficult and unpleasant ________

Rather difficult and unpleasant ________

A little unpleasant but no great problem ________

Easy and not unpleasant ________

46. How long does it usually take before you "recover your senses" in the morning after rising from a night's sleep?

0-10 minutes ________

11-20 minutes ________

21-40 minutes ________

More than 40 minutes ________

47. Please indicate to what extent you are a morning or an evening active individual.

Pronounced morning active (morning alert and evening tired) ________

To some extent, morning active ________

To some extent, evening active ________

pronounced evening active (morning tired and evening alert) ________

APPENDIX B: SLEEP LOG

SUBJECT NUMBER ____________   START DATE FOR THIS SLEEP LOG ______________________

	0000	0200	0400	0600	0800	1000	1200	1400	1600	1800	2000	2200	0000	ALERTNESS
MONDAY														
TUESDAY														
WEDNESDAY														
THURSDAY														
FRIDAY														
SATURDAY														
SUNDAY														

MARK PERIODS WHEN YOU SLEEP (TO NEAREST HALF HOUR) WITH A LINE WITH AN S AT EACH END. MARK DUTY PERIODS WITH A LINE WITH A D AT EACH END. ESTIMATE YOUR LEVEL OF ALERTNESS DURING EACH DUTY PERIOD IN THE BLOCKS AT THE END OF EACH DAY'S RECORD, USING THE SCALE BELOW.

VERY SLEEPY 0 — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 VERY ALERT

TABLE 1: SLEEP PER 24 HOURS AND SLEEP EPISODES PER WEEK

WEEKS	ACTIGRAPH SUBJECTS				ALL SUBJECTS	
	ACTIGRAPHS		SLEEP LOGS		SLEEP LOGS	
	HOURS	EPISODES	HOURS	EPISODES	HOURS	EPISODES
1	7.0	9.7	7.5	10.9	7.5	9.2
2	6.8	10.2	6.3	10.2	6.5	9.3
3	7.0	9.8	6.9	9.8	7.1	9.6
4	6.7	10.6	7.3	10.6	7.1	10.4
5	6.4	9.4	6.5	9.2	6.9	9.4
6	N/A	N/A	7.1	8.2	6.9	9.6
TOTAL	6.6	9.6	6.7	9.8	6.9	9.6

TABLE 2: PERFORMANCE AND MOOD

THIRD OF VOYAGE	PSIONS					SLEEP LOGS
	VECTOR		MOOD SCALES			
	%CORR	RT CORR	CALM	CHEERFUL	ALERT	ALERT
1	85%	1.0 SEC	9.1	11.6	10.3	12.6
2	86%	0.9 SEC	9.0	11.1	10.3	12.4
3	86%	0.9 SEC	9.2	10.9	10.3	12.0

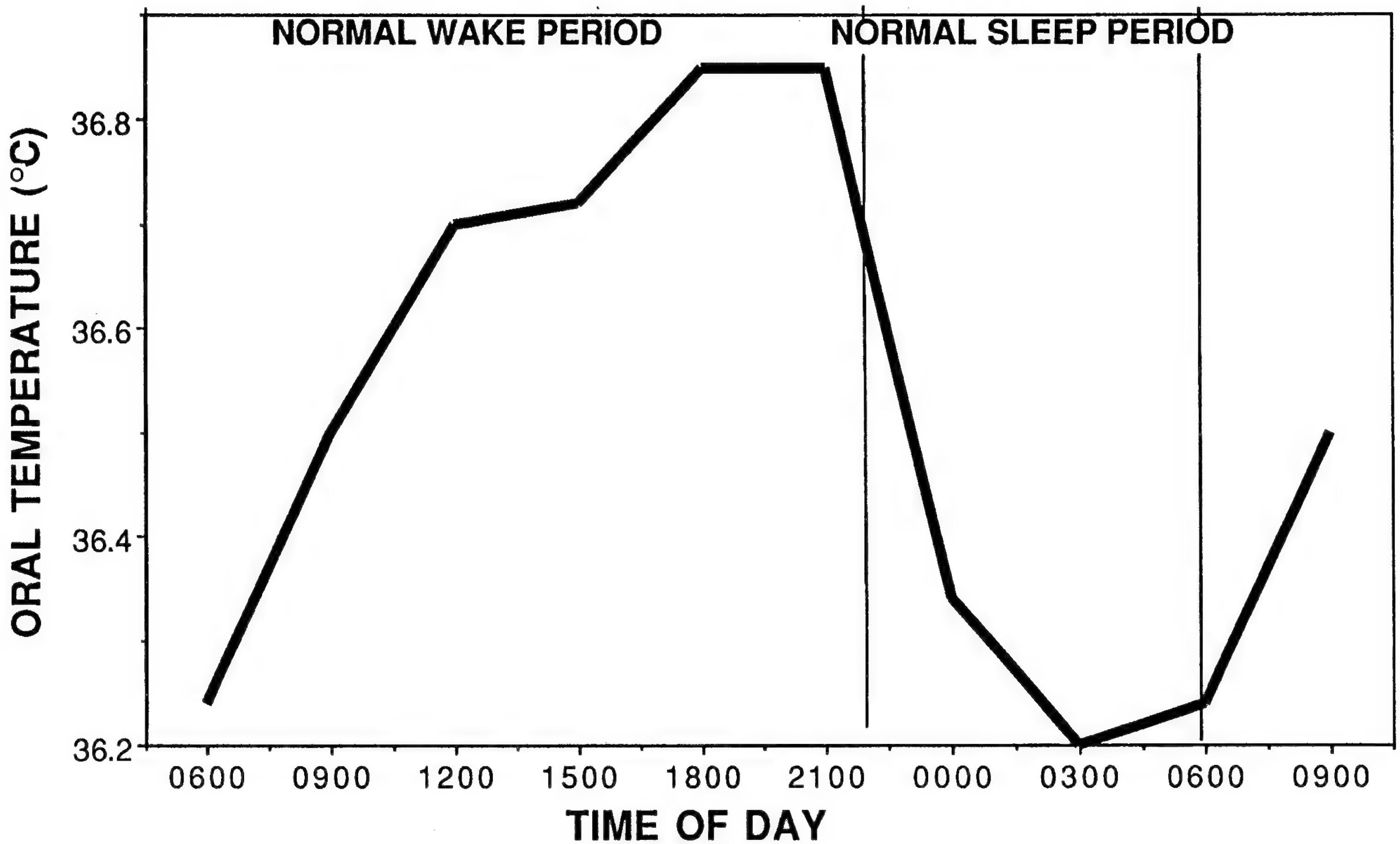

Figure 1: Circadian Rhythm of Body Temperature

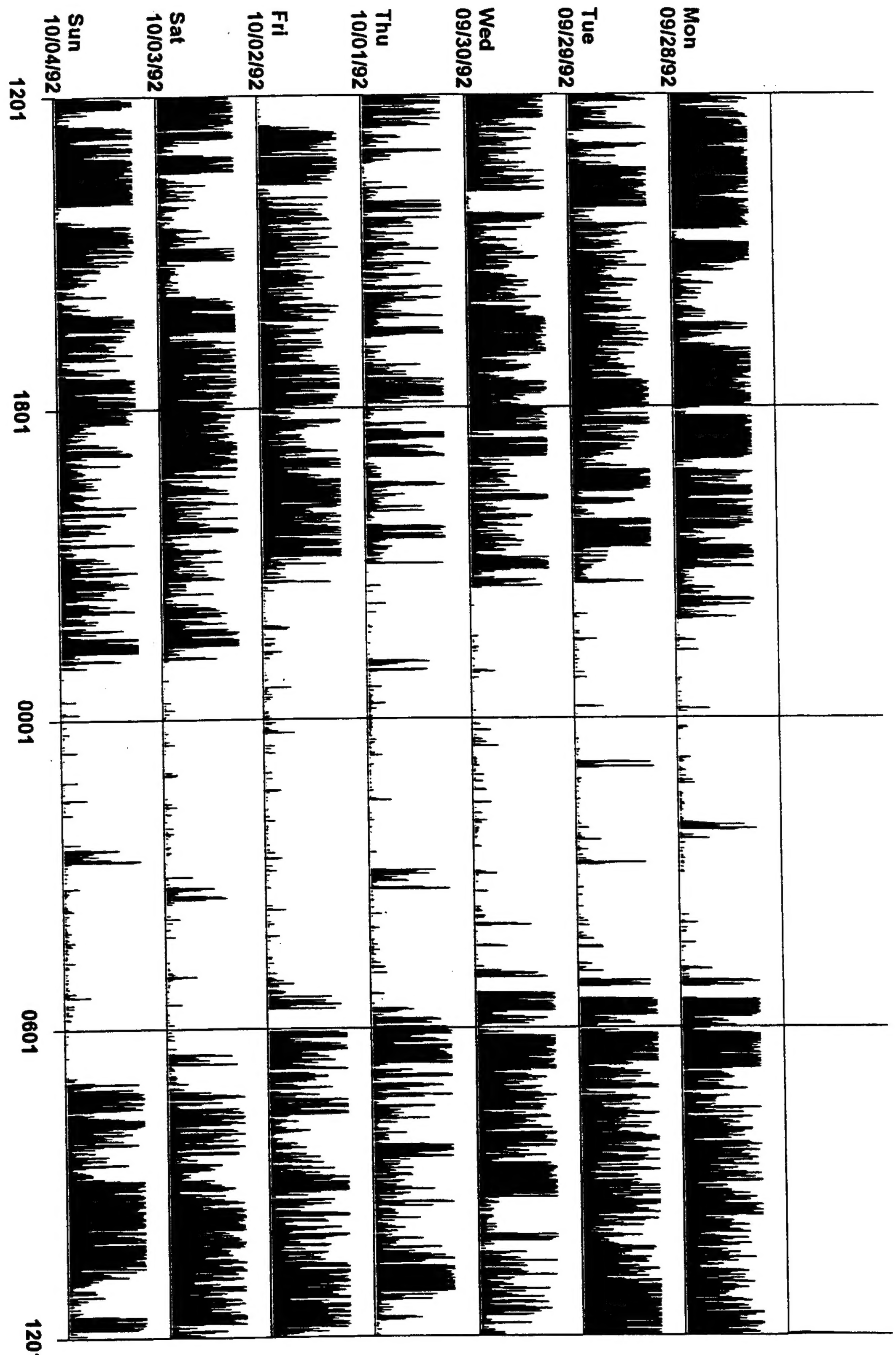

Figure 2: Actigraphic Record for 24-Hr Day

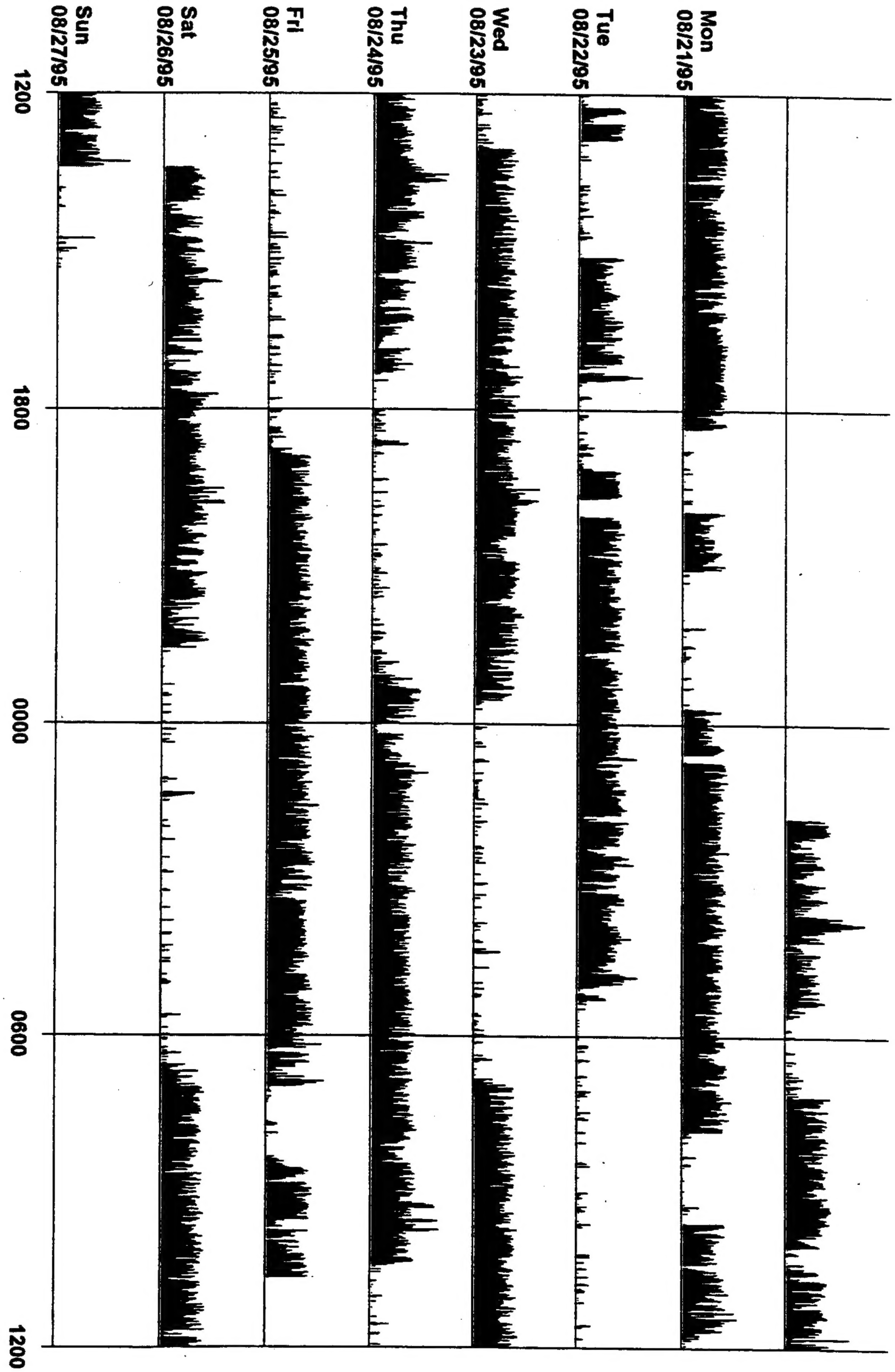

Figure 3: Actigraphic Record for 18-Hr Day

PERCENT OF SUBJECTS ASLEEP

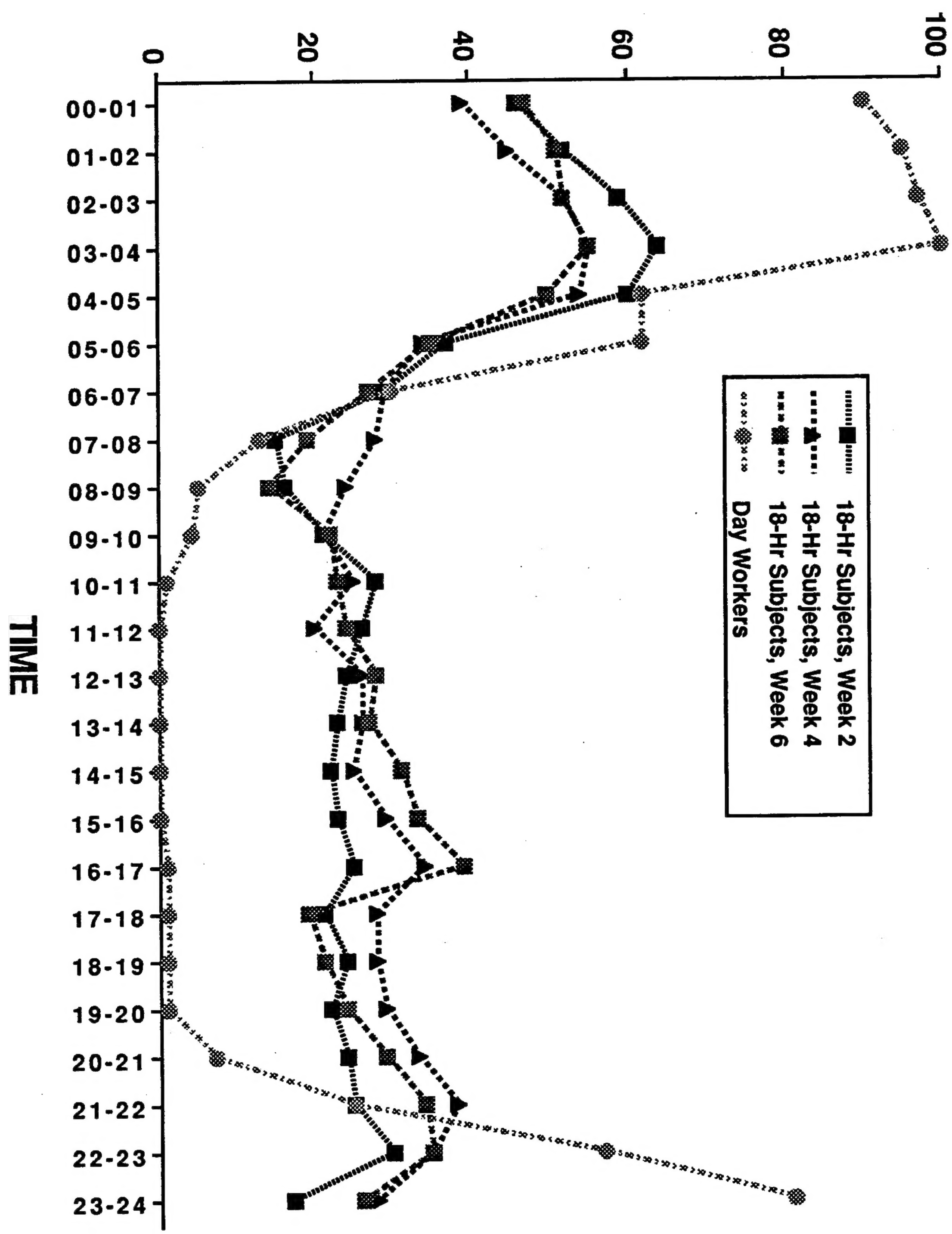

Figure 4: Percent of Subjects Asleep by Hour of Day

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13. ABSTRACT ***(Maximum 200 words)*** Circadian rhythms are fluctuations in physiological and behavioral parameters, cycling at a rate of about once every 24 hr, which are controlled by a biological clock. The endogenous circadian clock has been shown to cycle at a rate (tau) unique to each individual that is generally longer than 24 hr (24.25-25 hr). The most accurate method for determining tau is a laboratory protocol called forced desynchrony. In forced desynchrony, subjects are isolated from time cues and bright light. The sleep-wake schedule is lengthened or shortened to the point that it is physiologically impossible for a person to synchronize with. Under these conditions, circadian rhythms free run at the cycle length of the endogenous clock. The submarine 6-on/12-off schedule is very similar to such protocols, requiring subjects to live by an 18-hr day under conditions of isolation from bright light. A study of personnel living on this schedule aboard a submarine was completed. Measures included the circadian rhythm of salivary melatonin, sleep logs, actigraphs, and a performance assessment battery (PAB) administered on hand-held computers. Preliminary results from the PAB, the sleep logs, and the actigraphs are presented. Subjects appear to get sufficient sleep and to maintain acceptable performance levels on this work schedule.

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